# Phased Array Weather / Multipurpose Radar

M. Yeary[1], G. Crain[1], A. Zahrai[2], R. Kelley[1], J. Meier[1&2], Y. Zhang[1],
I. Ivic[2], C. Curtis[2], R. Palmer[1], T.-Y. Yu[1], R. Doviak[2]

[1]Atmospheric Radar Research Center
University of Oklahoma
Norman, OK USA

[2] National Severe Storms Laboratory
NOAA
Norman, OK USA

***Abstract*—The first phased array radar dedicated to weather observation and analysis is now instrumented with eight, simultaneous digital receivers. The addition of these additional channels will enable the use of advanced signal processing to improve signal/clutter in an adaptive mode. Elimination of strong point and ground clutter returns from the low-level, volumetrically distributed weather cell returns is a new application of adaptive processing. The NSF funded 8-channel receiver has been added to the National Weather Radar Testbed (NWRT) system in Norman, OK to enable operation as a multi-function and/or adaptive processing system. This paper will describe the system concept, system installation and early results from fielded weather data returns.**

## I. INTRODUCTION

At the current time, a single-channel digital receiver is operational to mimic the current WSR-88D capability. The multi-channel digital data will foster a new generation of adaptive/fast scanning techniques and space-antenna interferometry measurements, which will then be used to improve numerical weather prediction via data assimilation. Differing from the conventional mechanically steered beam, the phased array is suited for multi-mission capabilities so that a variety of scatterers may be observed simultaneously with a high degree of fidelity. The development of this new receiver system will be an enabling tool for related research for the next decade.

The multi-channel receiver will collect signals from the sum, azimuth-difference, elevation-difference, and five broad-beamed auxiliary channels. One of the major advantages of the NWRT is the capability to adaptively scan weather phenomena at a higher temporal resolution than is possible with the WSR-88D. The aperture is shown in Figure 1. Volume coverage in 1 min or less vs. 4 min (the conventional WSR-88D scan rate) can be accomplished without comprising data accuracy. The multi-channel receiver will allow the direct implementation of interferometry techniques to measure angular shear and turbulence within a radar resolution volume. Access to the auxiliary channels will enable clutter mitigation and advanced array processing for high data quality with short dwell times. Potential benefits of high quality and high resolution data together with angular shear and turbulence include better understanding of storm dynamics and convective initiation, as well as better detection of small-scale phenomena including tornado and microbursts, ultimately leading to increased lead time for warnings, and improved weather prediction.

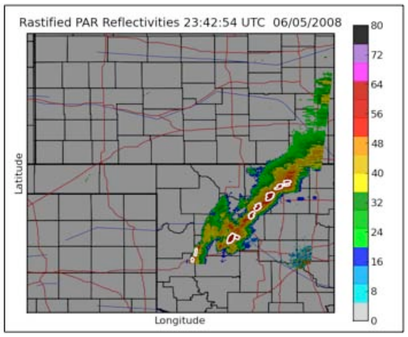


Figure 1: LEFT *the SPY-1A antenna that is used in Norman, OK was converted from Naval operations to primarily weather surveillance, with multi-function missions including aircraft detection.* RIGHT: *example data that has been collected with the current single change receiver.*

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14. ABSTRACT

**The first phased array radar dedicated to weather observation and analysis is now instrumented with eight simultaneous digital receivers. The addition of these additional channels will enable the use of advanced signal processing to improve signal/clutter in an adaptive mode. Elimination of strong point and ground clutter returns from the low-level volumetrically distributed weather cell returns is a new application of adaptive processing. The NSF funded 8-channel receiver has been added to the National Weather Radar Testbed (NWRT) system in Norman, OK to enable operation as a multifunction and/or adaptive processing system. This paper will describe the system concept, system installation and early results from fielded weather data returns.**

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Details about the current system can be found in [1]. The antenna is a passive array comprised of 4,352 elements. The array is located 40 feet above ground level. The antenna is mounted on a pedestal capable of rotating the antenna at 18 degrees per second. A 90 degree sector can be scanned in azimuth without moving the pedestal. Elevation scans are strictly electronic, no physical movement in elevation is possible. The system employs a retrofitted WSR-88D transmitter, and several salient features are:

- *Frequency: 3200 MHz*
- *Peak power: 750 KW*
- *Beamwidth: 1.53 degrees, transmit boresight, and 1.72 degrees receive*
- *Pulse width: 1.57 us (short)*
- *The sensitivity defined with a SNR=0 dB is 5.89 dBZ at 50 Km*

As in the current system, access to the multi-mode functionality will be available for remote operation from the National Weather Center operations center. The addition of the multi-channel receiver system will allow the NWRT to be configured as a multi-function radar, which is consistent with national needs, [2]-[7]. Key areas of scientific research on the completed project will be oriented around several key areas, including these four:

**Beam Multi-Plexing** (BMX) – Rapid scanning is one of the primary motivating factors. A phased array radar can directly collect statistically independent samples by revisiting the region of interest through flexible beam steering to optimize the data quality [8]. Applications include tornadic observations and storm tracking.

**Generalized Sidelobe Canceller** -- The next motivating factor is the ability to implement spatial filtering, which is not possible with the conventional WSR-88D. Clutter filtering using signals from sidelobe cancellers (SLC) becomes essential to optimize radar performance [9]. Applications include BMX and refractivity measurements [10].

**Spaced Antenna Interferometry** -- The motivation for this application is to estimate crossbeam wind, shear, turbulence, and to resolve discrete targets and reflectivity inhomogeneities within the radar's resolution volume [11][12]. There is potential to improve forecasts and quantitative precipitation estimates based upon the assimilation of high resolution data. In addition, monopulse measurements will be made for improved aircraft detections.

**Data Assimilation** -- The final motivating factor is the ability to improve the existing data assimilation techniques by offering new state variables to gain a fuller description of the state of the atmosphere and to initialize numerical weather prediction (NWP) models [13].

# II. SYSTEM IMPLEMENTATION

## A. *Overview*

The SPY-1A antenna array was designed to provide robust monopulse and sidelobe cancellation capabilities. The functionality is facilitated by existing azimuth and elevation difference channels and additional sidelobe channels in addition to the primary sum channel. Currently only the sum channel is instrumented in the NWRT. Utility of the additional channels has received much attention among researchers. The difference channels, for example, can be used to estimate angular shear and turbulence, while the sidelobe channels can be useful in reducing obscuration of weather by stationary targets or ground clutter. The multi-channel receiver features 8 high-speed digital receivers to acquire and process eight signals simultaneously from the antenna array in real-time. Figure 3, similar to the one in [14], shows a simplified block diagram of the system. RF signals from the low-noise amplifiers (LNAs) that are mounted on the array are supplied to the analog receiver subassembly. After filtering and down-conversion, the analog receivers provide intermediate frequency (IF) signals to the digital receiver chassis which produces the digital time-series data suitable for ingest by processing and recording systems.

## B. *RF to IF Downconversion*

The RF signals from the antenna are initially amplified by LNA devices that are mounted on the back side of the array. The outputs from these amplifiers are introduced to the analog receiver subsystem for filtering and down-conversion.

For each channel, coherent conversion to IF is accomplished by two mixer stages using two local oscillator signals from the existing exciter chassis. In addition, a coherent reference signal and a trigger pulse from the existing real-time controller (RTC) are buffered and conditioned for the digital receiver modules. The first mixer stage converts the 3200 MHz input signal to 750 MHz using a 3950 MHz local oscillator signal (LO1) from the exciter. The bandpass filter selects the lower sideband at 750 MHz and attenuates the remaining mixer artifacts. The second mixer converts the 750 MHz signal to 50 MHz using a 700 MHz local oscillator signal (LO2) supplied by the exciter. Another bandpass filtering stage is needed to pass only the lower sideband. The resulting IF signals are buffered and supplied to the digital receiver chassis for processing. The digital receivers also require a coherent reference clock and a trigger pulse for synchronization. These two signals are available from the exciter and the real-time controller (RTC). They are split and conditioned for the next stage.

### C. *Digital Receiver*

The digital receiver chassis contains all of the equipment necessary to ingest the eight analog IF signals and produce a multi-channel digital data stream suitable for processing and/or recording by user equipment. The digital receiver modules convert the IF signals to discrete samples using 14-bit analog to digital converters (ADCs). Although these converters are capable of sampling in excess of 100 MHz, they are clocked at 80 MHz. Raw discrete samples are converted to in-phase and quadrature (I & Q) components and then filtered by programmable filtering stages. The resulting high data rates are not suitable for many conventional buses. Therefore, a very high-speed serial transport fabric will be used to reliably transfer all data to their required destinations.

### D. *Duplex-Diplex*

A critical component in development of the multi-channel receiver system that makes use of all ports available on the NWRT antenna is a computer-controlled, waveguide switch that can manage the distribution of the antenna sum beam signal between these receivers. The desired modes include switching the main beam signal between the in-place receiver and a new, sum-beam, receiver in a multi-channel receiver suite (diplex mode); or allowing the sum-beam return from the antenna to be shared between these two receivers: each receiver getting 50% (duplexed mode) of the energy from each radar return signal. This configuration will allow for comparative testing, and to ensure that the legacy system will be operational while the new one is being installed.

## III. Conclusions

Figure 2 depicts the recently installed system, located behind the array at the NWRT. At the time of this writing, the team is working very diligently to finish all of the embedded programming that is required by the Echotek based digital receiver system. After this, pattern measurements and initial testing will begin. Radar imagery will be ready soon.

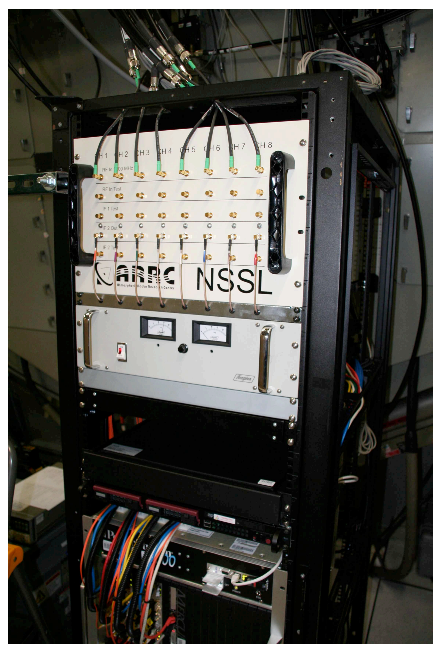


Figure 2: *Picture of the recently installed system. The top section contains the eight RF to IF downconverters, while the bottom section contains the eight digital receivers.*

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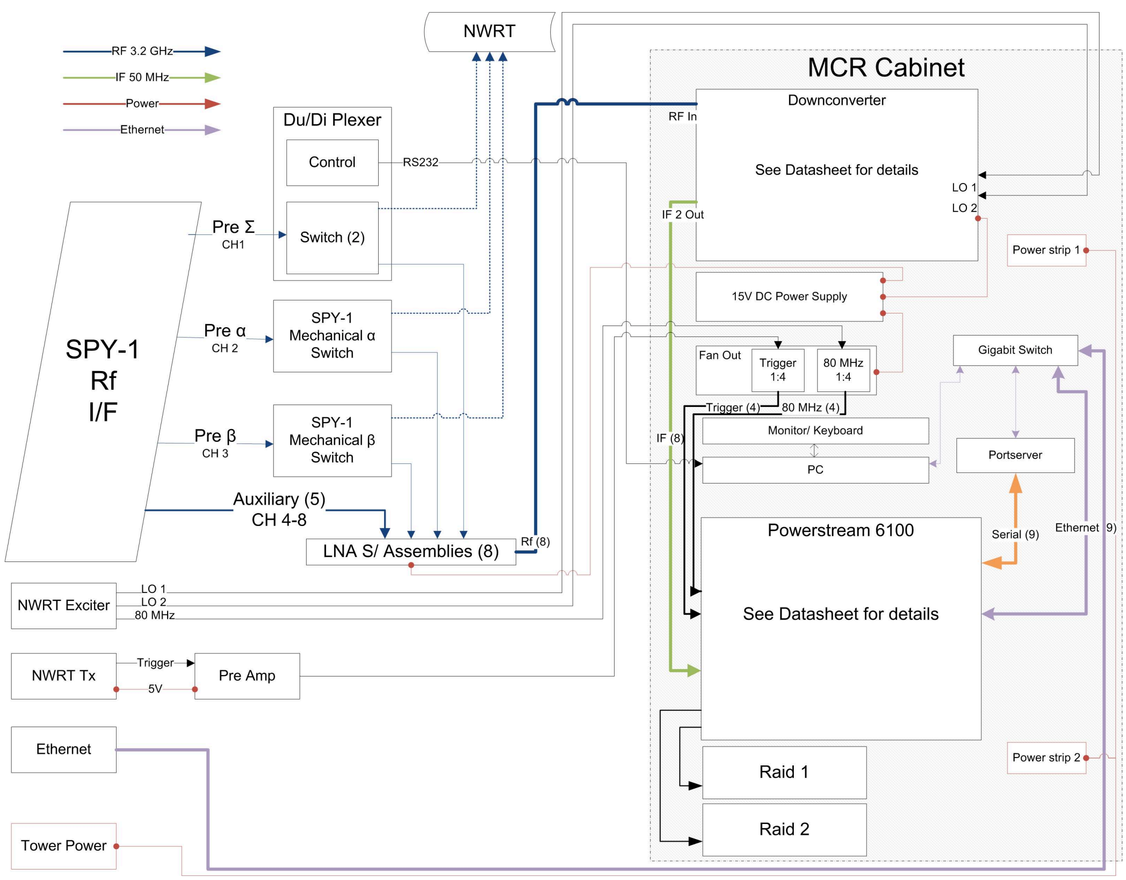


Figure 3: *Block diagram of the Multi-Channel Receiver at the National Weather Radar Testbed in Norman, OK*